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An Interactive Wire-Wrap Board Layout Program

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This article presents an interactive computer-graphics-based tool for specifying the placement of electronic parts on a wire-wrap circuit board. Input is a data file (currently produced by a commercial logic design system) which describes the parts used and their interconnections. Output includes printed reports describing the parts and wire paths, parts counts, placement list, board drawing, and a tape to send to the wire-wrap vendor. The program should reduce the engineer's layout time by a factor of 3 to 5 as compared to manual methods.

This program will benefit several projects at JPL, including the Advanced Digital SAR Processor and the Alaska SAR Processor. It is currently being used in the design of the DSN/SETI Spectrum Analyzer.

I. Introduction

The Communications Systems Research Section, Digital Projects Group (DPG), is currently designing several machines which will make extensive use of wire-wrap board technology. This technology allows a rapid turnaround time from design to production, and somewhat simplifies the design process. While printed circuit boards are cheaper to manufacture in quantity, the DPG's projects are mostly one-of-a-kind designs, and thus wire-wrap technology is more appropriate.

The DPG recently procured a Valid Logic Design computer system (a commercial product of Valid Logic Systems, Incorporated, of San Jose, California), which provides a tool for the computer-aided design of logic circuits. Several computer packages are available to turn such a design into a printed circuit board layout. However, no computer tool existed to turn the logic design data files into a physical layout of a wire-wrap board.

DPG engineers estimate that the manual layout of a board takes about 3 weeks. Computer-aided layout could reduce that time to 5 days or less. Since the DPG will design 30 or more boards in the next few years, a computer-based layout system will produce substantial cost and time benefits. Therefore, the decision was made to develop a system in-house.

II. System Description

Figure 1 shows a system block diagram of the logic design and layout system. The Valid Logic Design system and the file conversion program reside on an IBM 3270 AT/GX system. The rest of the system currently resides on a Masscomp

MC5600 system with an Aurora color graphics display. The programs written by the DPG include the file conversion program, the layout program, and the library editor program. These programs are written in the C programming language, and are machine independent and graphics-resolution independent.

The Valid Logic Design system produces files defining the parts used and the interconnections between them. The file conversion program reads these files and extracts the information needed by the layout system. The library editor program maintains the wire-wrap board descriptions and the physical-part description library.

The layout program reads the files provided by the file conversion and library editor programs, and then asks the engineer which wire-wrap board to use. Then the program displays a picture of the board; the designer can then select components from the logical design file and place them on the board graphically. The program optimizes wire routing, but the designer can manually override part or all of the routing. Several editing and display functions help the designer to accomplish these tasks. An intermediate file, called the layout data file, records the developing layout information while the design is in progress.

Once the layout is complete, the program prepares a wire-list tape to be sent to the wire-wrap vendor. Also, several reports are printed out to document the final design and to aid the engineer during debugging.

III. Wire Routing Optimization

One strong feature of the layout program is the ability to minimize wire path lengths. The basic problem is to minimize the wire length of an interconnected set of pins (a net). This is desirable for several reasons:

(1) Reduces cost.

(2) Reduces signal propagation delays.

(3) Reduces "ringing" effects and cross-coupling.

The wire routing optimization algorithm is an extension of the method described in [1]. The original algorithm treats all pins as identical. The extended algorithm recognizes special pins ("drivers" and "terminators") and groups these at the front and back of the net, respectively. While maintaining these groupings the entire net is minimized. This technique greatly reduces the need to manually override the results of the minimization process.

The time required to minimize a net increases rapidly with the number of pins in the net. To prevent long nets from taking extremely long times, the algorithm automatically stops if the minimum has not been exhaustively determined after a certain number of iterations, and uses the best order found so far. This "partial minimum" is usually close to the real minimum.

IV. Layout Program Description

A. Display Areas

Figure 2 shows the menu and screen display of the layout program. There are five distinct display areas:

(1) Board display.

(2) Selected part/net display.

(3) Data display.

(4) Parts list.

(5) Function menu.

1. Board display. This area shows the wire-wrap board and those parts which have already been placed on the board. This area also shows individual signal paths or highlights parts of a certain type if requested.

2. Selected part/net display. This area shows an individual part outline, along with its physical part name and pin names. Alternatively, this area shows the list of parts/pins connected to a single net.

3. Data display. This area shows data related to the current editing function and context. Examples of data shown are: the location of pin 1 of the currently selected part, the number of pins connected to the currently selected net, and the total wire length of the currently selected net.

4. Parts list. This area shows an alphabetically arranged list of the logical names of all the parts in the design. The list scrolls up and down, and the name of the currently selected part is highlighted. When the "show part type" function is selected, this area instead displays a list of physical part names.

5. Function menu. This area shows the available editing and display functions. Currently chosen functions are highlighted. The functions are:

a. Save and exit. This saves the current state of the layout design, and then exits to the operating system.

b. Abandon and exit. This exits to the operating system without saving the current design state. This takes less time than "save and exit," and is useful when you have experimented with the design but don't wish to save the results. If

any changes have been made, this function asks for confirmation before exiting.

c. Zoom out. This sets the board display area to view the entire board.

d. Zoom in. This sets the board display area to view a local area of the board, magnified by 3. The next pick on the board display area indicates the center of the area to be magnified. One of "zoom out" or "zoom in" will always be selected.

e. Show part. This shows the currently selected part outline, logical name, etc., in the selected part/net display area.

f. Show pin list. This shows the currently selected net (if any) in the selected part/net display area.

g. Replicate. This is similar to a "copy" operation. Each part in the currently selected group is deselected, and the next part in the logical parts list is selected in its place. Each new selected part is given the same initial location as its predecessor, so the new group is a "spatial replicate" of the old one. This new group may then be dragged around and placed as the old one was.

h. Suppress sorting. This prevents the program from performing net minimization each time a part is placed. If a part is connected to a particularly long net, sorting could slow down editing too much. Picking this function repeatedly toggles it on and off.

i. Group. This allows the user to specify, one at a time, a group of parts on the board display to be repositioned or removed. Each part picked on the board display is toggled between selected and deselected. Picking this function repeatedly toggles it on and off.

j. Group by box. This allows the user to specify, by corners of a rectangular area, a group of parts on the board display to be repositioned or removed. The next two picks on the board display define the rectangular selection area. Picking this function repeatedly toggles it on and off.

k. Show part type. This replaces the logical name list in the parts list area with a list of the physical part types used. Picking a physical part from this list causes all parts of that type to be highlighted in the board display area.

l. Show long nets. This highlights on the board display the wire path of the net with the greatest wire length. Picking this function repeatedly steps through successively shorter nets, displaying one at a time. Note that only already minimized nets are considered for this function.

Note that the functions "group", "group by box", "show part type," and "show long nets" are mutually exclusive, and that they set the selected part/net display as follows:

Function	Sets display to
Group	Nothing
Group by box	Nothing
Show part type	Show part
Show long nets	Show pin list

m. Undo. This reverses the effect of the last editing operation.

n. Long cursor. This changes the cursor to a full-screen crosshair. This is useful for aligning objects during placement. This option is toggled on and off by picking it repeatedly.

B. Editing Terms and Concepts

This section contains descriptions for performing most editing operations, using the Masscomp MC5600 system implementation of the layout program. This system uses a mouse for graphic input. In these descriptions, certain words have special meanings:

(1) "pick" means move the cursor over an object and press either outside button on the mouse.

(2) "place" occurs when you are dragging an object(s). When the object is located where desired, press either outside button on the mouse.

(3) "drop" means press the center button the mouse.

Note that you never need to hold a mouse button down (e.g., to drag an object). Always release the button immediately.

Placing, moving, swapping, and removing parts in the board display area, as well as displaying parts and net wires, overriding net minimization, and swapping pins are all accomplished by pointing the cursor at objects on the screen and pressing the mouse buttons. Certain keyboard keys have meaning as well.

The following concepts are basic to the editing philosophy.

1. Currently selected part. Normally, a single part is selected for editing operations. This part is highlighted both in the parts list and in the board display area. Also, the drawing of the part appears in the selected part/net display area. A

part may be selected either by picking its name from the parts list or by picking its outline from the board display.

When using the group functions, more than one part may be selected at once. All selected parts are highlighted, but no part drawing appears in the selected part/net display area.

2. **Placed vs dropped**. Each part is in one of two possible states: "placed" or "dropped." If it is placed, it has a fixed position on the board associated with it. If it is dropped it does not occupy a position on the board display.

3. **Currently selected net**. A net is selected by picking a signal name from the selected part display. When a net is selected, its net name, wire length, and number of pins appear in the data display, and if any pins from the net are in parts placed on the board display, these pins are highlighted as well.

C. How-to's

To place a new part, pick the part name from the parts list, then move to the board display and place the part in the desired position. The data display area helps by dynamically showing the pin location of pin 1 until the part is placed.

To move an already placed part, pick up the part by its outline in the board display, then move it to the new location and place it. Again you see the dynamic pin 1 location display.

To drop a part which is following the cursor, press the drop button on the mouse. The part outline will disappear and there will be no currently selected part.

To remove a part from the board, move the cursor to the part on the board display and press the drop button. The part will disappear from the board. Any currently selected parts (if not the one just removed) will remain selected.

To move a block of parts, first use the "group" or "group by box" function to select the desired parts. Next turn the group function off. Then move the cursor to the board display area and pick up the group, move it to the new location, and place it again.

To remove a block of parts, first select the group as described just above, then press the drop button.

To replicate a block of parts, first select the group as described above, then select the replicate function from the function menu. Each item in the current group is deselected, and the next item in the list is selected in its place. Then move the cursor to the board display area, pick up the new group, move it to its new location and place it again.

To select a part for display, pick the part name from the parts list. The part display will appear. Alternatively, pick the part outline in the board display, then place it immediately without first moving the mouse. The part display will appear, and the part will still be in place.

To display a net, first select a part which has at least one pin connected to the desired net. Then pick the connected pin from the part display in the selected part/net display area. The net name, length, and number of pins will appear in the data display area, and any pins connected to the net will be highlighted on the board display area.

D. Keyboard Commands

In certain contexts various keyboard keys are interpreted as commands. The keypresses are not echoed to the screen; the effect of each command is visually apparent on the screen. If a key has no meaning in the current context, pressing that key will merely result in a beep.

Pressing any cursor arrow key causes all currently selected parts to move to the next unoccupied pin position in the arrow direction. If there is no unoccupied position left in the indicated direction, the program beeps.

Typing the "/" key drops each currently selected part and selects the next part in the parts list. If the previously selected part was "placed," it stays where it was. Typing the "\" key selects the previous part in the same manner.

Typing any alphabetic character or numeric digit causes the parts list display to move to part names starting with that character or greater.

Typing the "+" key advances the parts list display by 3/4 page. Typing the "-" key backs up the parts list display by the same amount.

Typing a carriage return is the equivalent of pressing the mouse "place" or "pick" button.

Typing the DEL key is the equivalent of pressing the mouse "drop" button.

By combining the above key commands it is possible to rapidly place arrays of parts whose names are alphabetically close together.

V. Conclusions

The DPG has used manual and semiautomatic wire-wrap board layout methods for many years. This in-depth applica-

tions knowledge, combined with graphics expertise, has produced a very useful computer tool. Layout program features are confined to those operations which are truly useful to a design engineer. Output reports are organized to aid circuit testing. The input file format is simple and generalized, easing the process of interfacing to any design system.

The layout program has taken about 3 workmonths to produce. The DPG alone will lay out more than 30 board designs using this system, thus saving at least 1 workyear of effort on the DSN SETI spectrum analyzer. This same technique could be used widely throughout NASA to improve the digital systems design process.

Reference

[1] M. J. Grimm, "A simple algorithm for the metric traveling salesman problem," in the *TDA Progress Report 42-78*, pp. 108-114, Pasadena, California: Jet Propulsion Laboratory, August 1984.

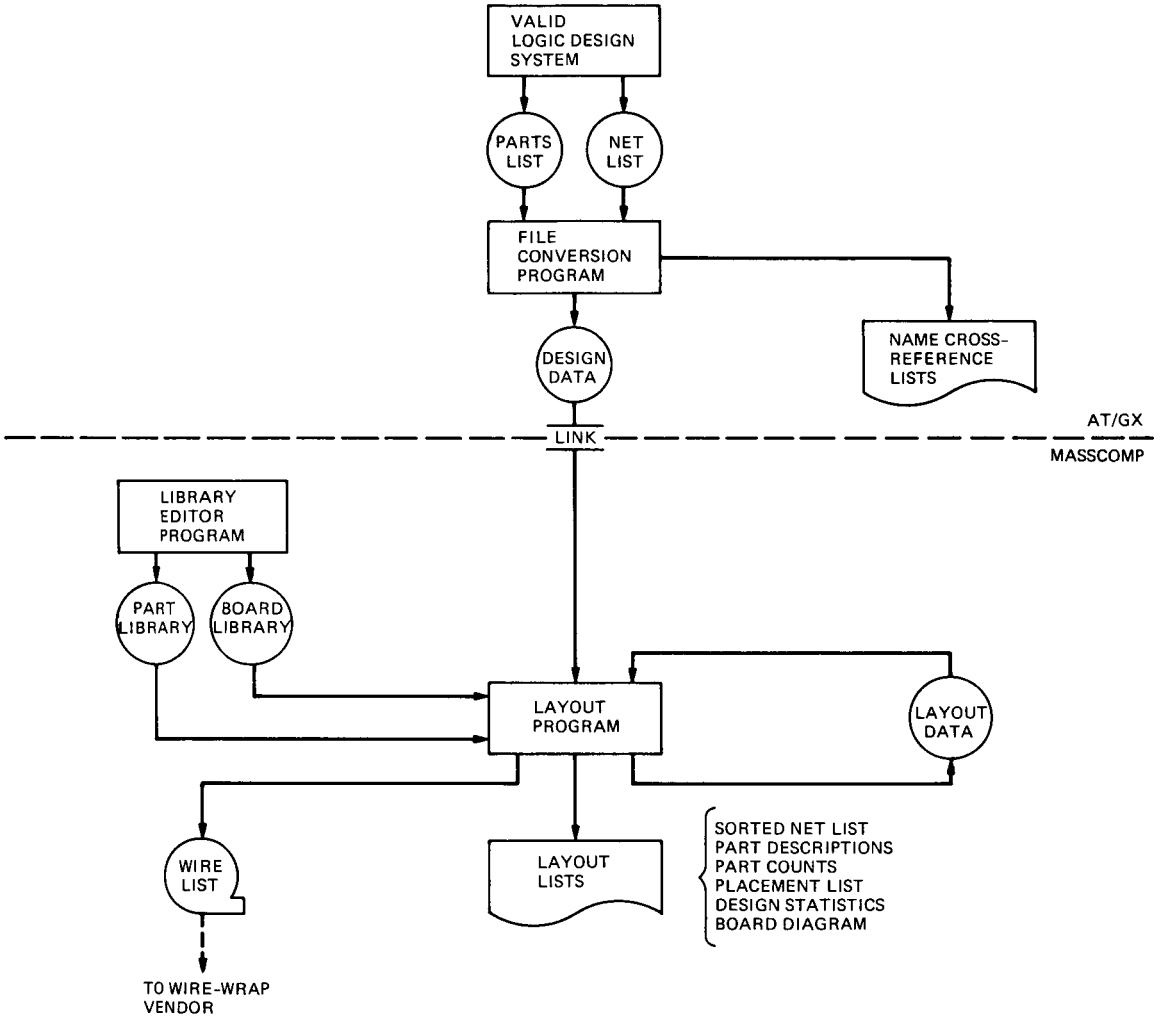

Fig. 1. Layout system

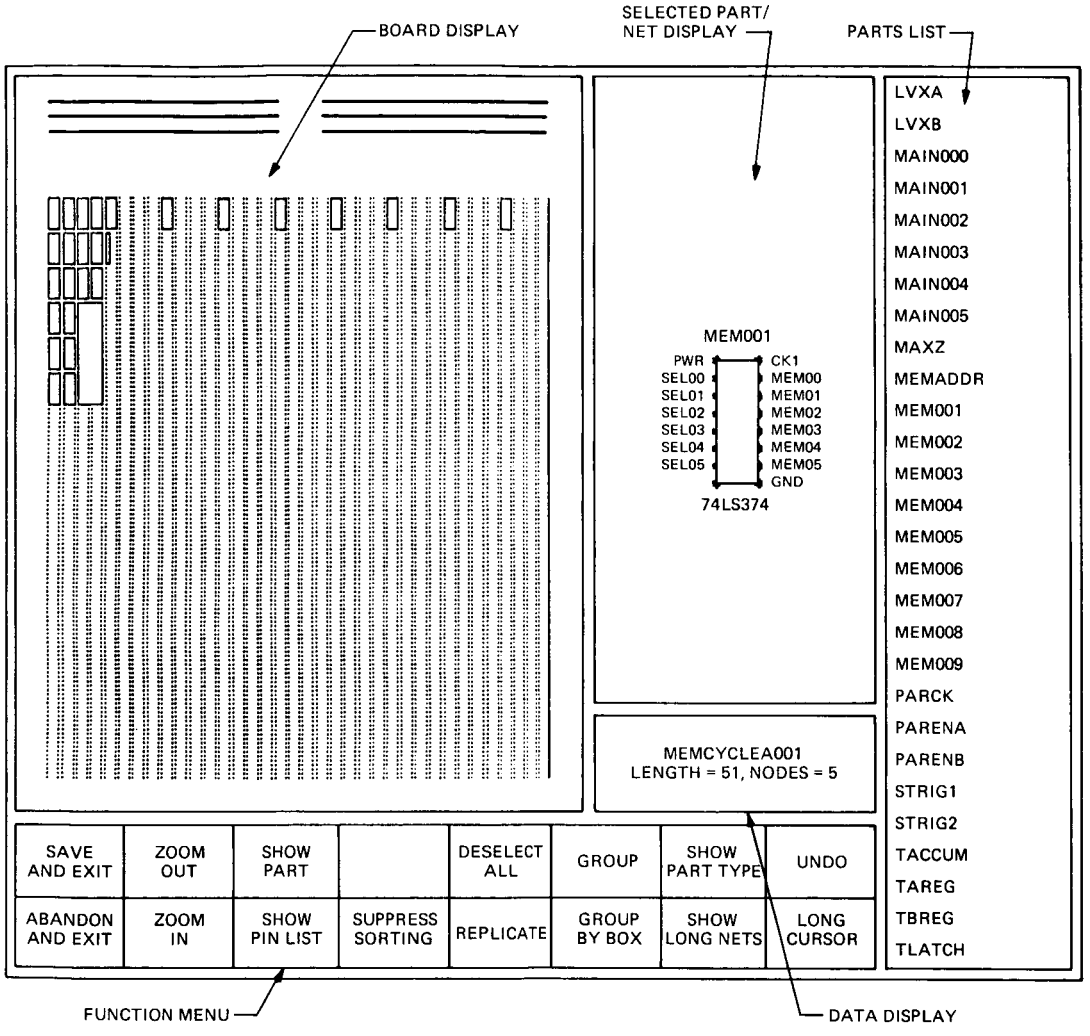

Fig. 2. Layout program screen display